PENNATULARIANS

(Umbellula)

BY

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OSLO

eat collection of sea-pens of the genus *lula* was brought together by the Swedish Sea Expedition. However, only three s were represented, one in one specimen, ner two in great numbers. The specimens aught by the prawn-trawl, and a glance distribution of species and specimens in fferent hauls indicates that in the deep e pennatularians evidently mostly occur ches. In such localities the population e considerable as e. g., at the station 363 No. 8), where no less than 157 specimens *bellula güntheri* were caught.

, on the other hand, surprising that also s case the bulk of the specimens were ratively small, that all somewhat larger ens had been mutilated, and that speci- of the largest dimensions were missing r finds indicate that *Umbellula güntheri* mes attains a larger size than that ob- in the present collections). This, how- evidently must be attributed to the gear.

g more than 40 years we had from the Biological ity Station at Drøbak worked with common dred- nall Agassizdredges and prawn-trawls in some n the Oslo-fjord year after year and only caught e of medium-sized *Funiculina quadrangularis* in 0 m depth. However, a few years ago an occa- weep over the same bottom field with a line hung h-hooks and stretched between a couple of otter- brought up several extraordinarily large colonies *iculina* and displayed that in these grounds the is quite common although prawn-trawls are wor- over them so to say daily in the season.

ger specimens of the slender, deeper-living tularians are doubtless both deeper and ratively more vigorously anchored in the y bottom than smaller specimens. They are, therefore, not so easily uprooted, and their flexibility probably also contributes to their ability to avoid the catching gear. The ground rope of a trawl will generally pass over them, when they do not catch in some nook or other, e. g., where rope and otter-board meet.

Heed being paid to such circumstances it nevertheless seems defensible to maintain that the catches of the Swedish Deep-Sea Expedition indicate that the *Umbellula* species generally occur in patches. How far this depends upon the special nature of the bottom deposits cannot be judged at present; the observations at disposal are yet too few and casual.

It was rather astonishing to see that only in one case, viz., haul No. 4 (st. 342) two species were found in one catch (to wit, 45 *Umbellula güntheri* and 7 *U. carpenteri*).

Sea-pens were gathered in the following places:

Station 342 (Haul No. 4), 16.VII.1948:

N 01° 03′, W 18° 40′
00° 58′, 18° 37′

Depth 5250—5300 m.

45 *Umbellula güntheri*
7 — *carpenteri*.

Station 357 (Haul No. 6), 26—27.VII.1948:

N 02° 26′, W 39° 26′
02° 24′, 39° 12′.

Depth 4474—4430 m.

1 *Umbellula durissima*.

Station 363 (Haul No. 8), 3.VIII.1948:

N 12° 22′, W 52° 00′
12° 13′, 51° 44′.

Depth 5044—5033 m.

157 *Umbellula güntheri.*

Station 371 (Haul No. 10), 20.VIII.1948:

N 24° 12′, W 63° 23′
24° 28′, 63° 18′.

Depth 5850—5860 m.

5 *Umbellula güntheri.*

Station 376 (Haul No. 11), 27—28.VIII.1948:

N 30° 19′, W 55° 56′
30° 30′, 56° 19′.

Depth 5600—5340 m.

4 *Umbellula güntheri.*

Station 387 (Haul No. 13), 7.IX.1948:

N 40° 33′, W 35° 24′
40° 34′, 35° 52′.

Depth 4600—4540 m.

9 *Umbellula carpenteri.*

On the taxonomy of *Umbellula*

Certainly too many species have been described within this genus. Several of them have been described too cursorily, and in many cases stress has been laid on characters and proportions which no doubt are correlated with different states of contraction. To this it may be added that the few and scattered specimens brought home by different expeditions have not allowed a detailed study of one species, its development and variations. Also the conscientious investigations of Koren and Danielssen (1884) and Jungersen (1904) suffer from the scanty numbers of specimens.

Among the characters generally used in descriptions of the species of *Umbellula* two distinguish themselves as more important than the others, viz., occurrence or absence of spicula in the surface tissues of the polyps and the shape of the axis the section of which may be more or less circular, or quadrangular (with more or less deeply excavated sides).

Hickson (1916) evidently mistook the intentions of Kükenthal and Broch (1911) when they investigated the existence of calcareous concretions or spicula in the interior tissues of the stalk to show that this is common to pennatularians. As a taxonomic character it is of no use in *Umbellula*, probably also in other genera.

According to his key to species Kükenthal (1915) seems to attach more weight to the shape of the axis than to the occurrence or absence of spicula in the polyps (I prefer to use the term of spicula for the calcareous formations in the superficial layers alone, and not for the calcareous concretions or corpuscles of the inner layers of the bulb). This, however, may well be a fortuitous arrangement. Nevertheless, in this case I prefer to follow Hickson (1916) and arrange the *Umbellula* species in two main groups: those with spicula, and those without spicula.

The common spiculum type in bipinnatularians is rod- or needle-shaped with three longitudinal keels or flanges. They may be quite straight or more or less twisted screw-like round the longitudinal axis of the spiculum. Such three-flanged spicula occur e. g., in *Umbellula güntheri* and have been figured by Kükenthal (1913); nevertheless Hickson (1916) describes them as »rod-like», evidently overlooking that the drawings distinctly display the keels and that this feature is also mentioned in the text. On the other hand, it is correct to describe the spicula in *Umbellula durissima* as rod-like or roughly fusiform (see below). It is difficult to say whether these spicula are more primitive or have developed from three-flanged forms by secondary reduction of the ridges. This question, however, is here of minor importance, the

is that their shape and structure are cteristic in the species.

CKSON (1916) says that he cannot follow ourse of KÜKENTHAL (1915) who regards hape of the axis — whether round or angular in section — as a taxonomic cter of main importance. He, moreover, sts that this character cannot be traced ite young specimens. I cannot agree with SON here. Also in the tiniest axes of the colonies from the Swedish deep-sea collec- he shape could with some care be settled. connection with the characters of the axis necessary to dissociate oneself from an tical use of characters like the more or owed shape or a spiral twist of the upper just below the polyp cluster. Although xis may in some cases be rather stiff, it *Umbellula* generally be slender and pretty le especially in its upper part. When the mens are picked out of the nets the polyp r will owing to its weight therefore be nlous in most cases, especially when there ore polyps in it. In their natural conditions olyp cluster will probably never be pendu- — On the other hand, we must also pay to the fact that the specimens during the are exposed to unnatural conditions and also to injury, and that they are more or ontracted when they arrive in the hand investigator. The stronger contractions in incurvings or twistings of the upper like that of *Umbellula durissima* of the nt collection (see table I, fig. 5) or *Umbel- veberi* of HICKSON (1916) from the Siboga dition. Such characters cannot be used as ic criteria.

character which has been used in some is the presence or absence of a tentacle siphonozooids. This, however, seems to doubtful value. Already HICKSON (1916) d against the use of it, because the tiny le may be torn away or withdrawn into ttle siphonozoid and is therefore of little the taxonomy.

Great stress has been paid to the length of the tentacles, whether longer or shorter than the body of the autozooids. Nobody seems to have paid heed to even this character being of more doubtful value than any other. As mentioned below and also in a previous paper (BROCH 1913) the tentacles may be of very different length in one autozooid according to the state of contraction, and on the other hand the contractions of body and tentacles are by no means proportional.

Species collected by the Swedish Deep-Sea Expedition

Umbellula güntheri Kölliker 1880.

(Plate I, Fig. 1, textfig. 1—3).

? *Umbellula Thomsonii*, Kölliker 1874 a, Ueber den Bau und die systematische Stellung der Gattung Umbellularia, p. 13.

? — *Thomsonii*, Kölliker 1874 b, Die Pennatulide Umbellula und zwei neue Typen der Alcyonarien, p. 10.

? — *Thomsonii*, Kölliker 1880, Report on the Pennatulidae. Challenger Zool. *1*, p. 19.

— *güntheri*, Kölliker 1880, Report on the Pennatulidae. Challenger Zool. *1*, p. 18.

— *leptocaulis* + *U. simplex*, Kölliker 1880, l. c. p. 20.

not — *güntheri*, A. Agassiz 1888, Three cruises of the U. S. Coast and Geodetic Survey Steamer »Blake», p. 314.

— *güntheri*, Studer 1894, Note préliminaire sur les Alcyonaires, p. 57.

— *crassiflora*, Roule 1905, Notice préliminaire sur les Pennatulides recueillis par le »Travailleur» et »Talisman», p. 456.

— *intermedia* + *U. rosea* + *U. Köllikeri*, Thomson and Henderson 1906, An Account of the Alcyonarians. I The Alcynarians of the Deep Sea, p. 94, 95, and 97.

— *Hendersoni*, Balss 1910, Japanische Pennatuliden, p. 68, footnote.

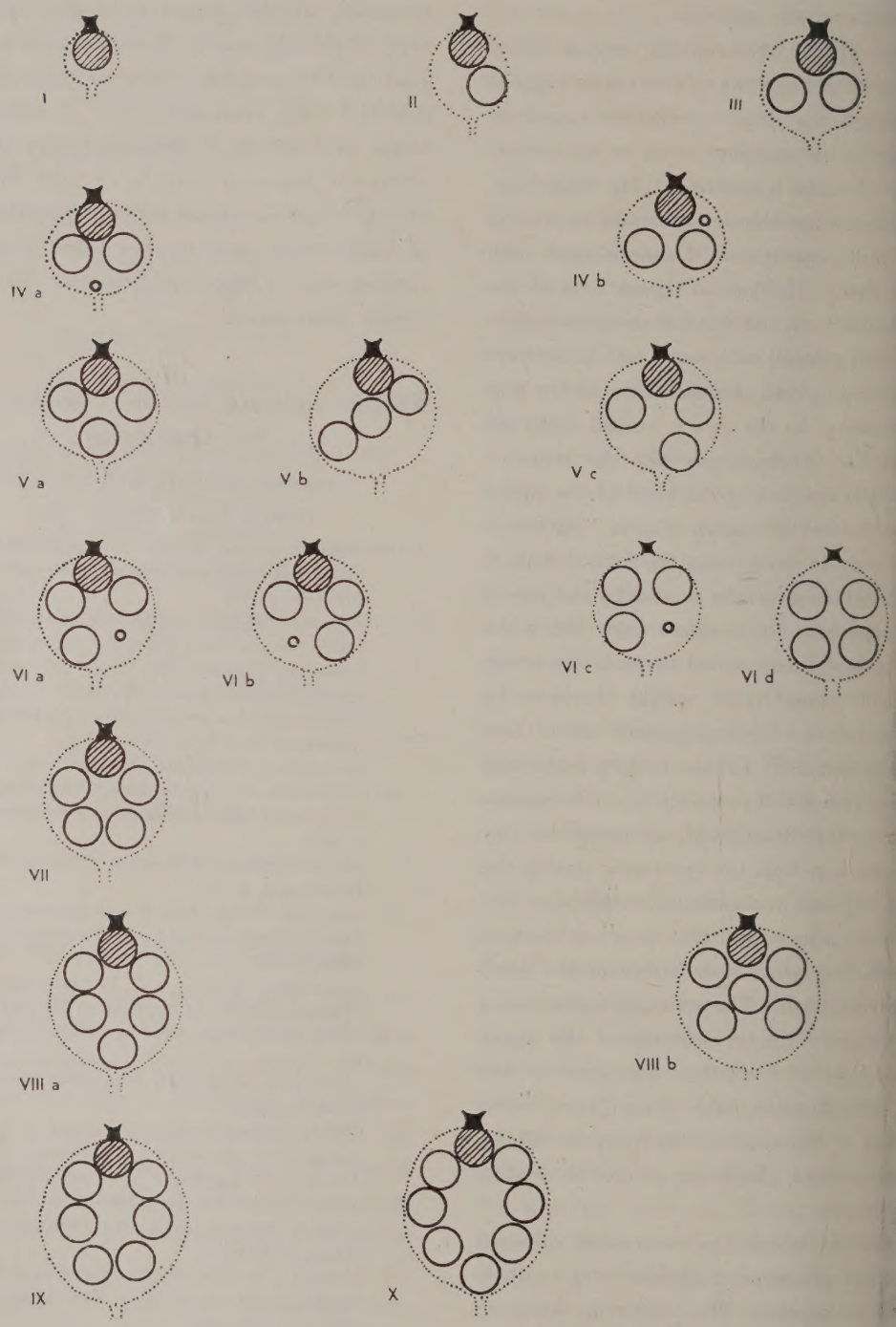
— *Güntheri*, Broch 1913, Pennatulacea, p. 3.

— *güntheri* + *U. thomsonii* (?) + *U. rosea* + *U. crassiflora* + *U. intermedia* + *U. simplex*, Kükenthal 1915, Pennatularia, p. 52, 54, 56, 57, and 58.

— *güntheri*, Hickson 1916, The Pennatulacea of the Siboga Expedition.

— *güntheri* + *U. thomsonii* (?), Deichmann 1936, The Alcyonaria of the Western Part of the Atlantic Ocean, p. 268, 269.

The extensive collections give a good picture of the succession in the development of the autozooids from the primary polyp to the largest clusters of the collections with their 8 autozooids



Text-fig. 1. *Umbellula güntheri*. Diagrams showing successive stages (I—X) in the development of the clu autozooids, from a primary polyp only (I) to a cluster with 8 autozooids. The primary polyp is shaded in the di (Comp. the text).

e simple circle ventrally and laterally on vollen part of the rachis. There is always ader or narrower dorsal field without oids, in part depending on the state of action. The axis terminates in the wall primary polyp and never juts out above ng an upper »spine» like that of *Umbellula teri* (see below).

successive formation of autozooids is out- in text-fig. 1. In two small specimens he primary polyp is present (No. 1 and 2 table, text-fig. 2); one of these specimens oduced in plate I, fig. 1. — The successive econdary autozooids appear as shown in agrams II and III (text-fig. 1). The third oid normally arises below the interval en the two first ones (IV a), but an excep- o this was observed in one case (IV b), a quite small bud was found laterally en the primary polyp and the next auto- this, however, seems to be an anomaly. rs with four full-grown autozooids nor- exhibit a regular cross-arrangement (V a), one case (V b) the three secondary auto- formed one oblique row below the pri- polyp. Another exception was observed o wit, that the lower one of the secondary oids had been removed a little to one so that a somewhat broader interspace risen between it and the upper, secondary oid of the other side (V c). This, however, re likely a transition to the next stage and b), where the secondary autozooid is developing in the interval; it seems ous, whether No. 4 arises on the left or ght side.

copious collection shows that the follow- ages (VII, VIII a, IX, and X) are very m, new autozooids successively arising y and ventrally on the swollen part of his. In specimens with 5 to 8 autozooids, lyps form a simple wreath, and only in se (VIII b) an anomaly was seen with a l autozooid below the primary polyp. two specimens no primary polyp was found (VI c and d); it seems most likely that the primary polyp has been reduced, but no trace could be found. Otherwise these clusters at first sight looked quite normal, corresponding to the stages VI and VII of the normal series.

It is a question, how great the specimens of *Umbellula güntheri* can be. The species does not seem to belong to the greater *Umbellula* species. We shall, however, return to this question further on.

Another question arises, viz., whether a correlation exists between the size of the specimens and their numbers of autozooids (see table of measurements, text-fig. 2). The numbers of intact colonies measured only amount to 48, which are arranged in the diagram in text-fig. 3. In spite of the low figures the diagram furnishes a good idea of the great variability among the specimens as to growth and numbers of autozooids. Specimens with 3, 4, and 5 polyps are best represented and show variations of total lengths of the specimens from 5.6 to 20 cm, 6.4 to 37 cm, and 9 to 57 cm respectively. This enormous variation is most astonishing, and it is at present difficult to give a plausible explanation. On the other hand, the diagram exhibits a certain regularity, a slow but uniform growth in the smallest specimens, whereas the size of the largest specimens increases with the rising number of autozooids. The variation in size is accordingly much greater in specimens with several autozooids than in such with a lower number.

In the great collections of specimens up to 60—70 cm total length a stalk is exceedingly difficult to trace, and I had to give it up. The basal »bulb» seems only feebly developed, if at all, and a limit between it and the »region IV» of HICKSON (1916) cannot be discerned. His »region IV», the upper part of the stalk or peduncle quite gradually goes over into »region III», the rachis between the stalk and the swollen upper part of the rachis with siphonozooids and autozooids (HICKSON's region II and I). The lower part just above the bulb is comparatively fleshy and

Nr.	Total length	Upper swollen part of rachis: Total length	Upper swollen part of rachis: Part below the auto zooids	Primary polyp: length of body + tentacles	Secondary autozooids: length of body + tentacles						Diame the Below the swelling
1	31	—	—	1.5+ 1.3							0.1
2	42	—	—	3+ 3.5							0.1
3	42	—	—	2.5+ 2.6	2.0+ 2.4						0.2
4	56	incurv.	0.3	5.5+ 4.5	2.5+inverted;	2.0+inverted					—
5	66	—	—	6+ 8	4.5+ 3;	4+3					—
6	110	—	0	4+ 3.5	5.5+ 3;	5+ 3					0.5
7	145	15	5	6+ 7	5+ 7;	11+ 9					0.5
8	200	13	4	5+ 6	11+ 8;	8+ 4					—
9	64	—	—	5+ 4	5+ 6;	4+ 3.5;	2+ 2				—
10	74	—	—	4.5+ 6	5+ 6;	5.5+ 3;	6+ 4				—
11	152	14	4	5+ 5	9+ 4;	8+ 6.5;	9+ 5				0.4
12	160	15	3	11+ 6	11+ 7;	9+ 9;	9+ 9				0.6
13	160	15	5.5	7+ 7	10+ 5;	7+ 7;	5+ 3				0.7
14	181	11	2.5	2+ 2	6+ 3.5;	6+ 3;	5+ 4				0.5
15	185	15	4.5	3+ 3	8+ 5;	8+ 7;	6+ 2.5				0.5
16	225	15	5	7+ 3	9+ 5;	9+ 6;	3+ 1				0.4
17	236	14	4	4.5+ 5.5	10+ 8;	8+ 8;	9+7				0.5
18	268	16	5	6+ 9	14+ 7;	15+ 7;	10+ 7				—
19	288	14	4	6.5+ 5.5	10+ 6;	8+ 6;	11.5+ 9				0.7
20	350	14	3	11+ 8	11+ 8.5;	10+10;	12+ 9				0.6
21	370	—	—	10+10	9+14;	14+ 9;	5.5+ 8				0.5
22	90	—	—	4.5+ 5.5	6+ 4.5;	4.5+ 6;	6+ 4;	3+ 3			—
23	152	17	5	9+ 9.5	13+ 6;	13+ 8;	15+ 7;	7+ 4			0.5
24	188	12	3	10+ 8	11+ 8;	14+ 9;	12+ 9;	15+10			0.7
25	190	16	5	7+ 7	13+ 9.5;	13+ 8.5;	12.5+ 9;	10+ 7			0.7
26	245	15	4	5+ 4.5	9+ 7;	9+ 5;	10+ 5;	10+ 5			0.7
27	250	17	6	12+ 9	16+ 7;	15+ 9;	14+11;	17+ 9			0.7
28	255	15	5	absent	11+10;	10+10;	11+10;	11+ 7			0.9
29	273	21	8	9+ 7	13+10;	11+ 6.5;	14+ 7.5;	8+10			0.9
30	286	18	4	8+ 7	13+ 8;	10+ 8;	12+ 7;	10+ 8			0.6
31	290	17	5.5	8+ 7	10+ 9;	7+ 6;	10+ 4;	10+ 5			0.8
32	298	17	6	9+11	13+11;	15+12;	14+ 9;	13+10			1.0
33	310	17	5	5+ 5	10+ 7;	9+ 5;	9+ 6;	9+ 5			—
34	355	22	7	10+ 7	13+ 9;	12+ 9;	14+10;	14+ 6			1.0
35	385	17	5	5+ 2.5	14+ 8;	17+ 8.5;	14+10;	17+ 8			0.7
36	385	14	7	absent	12+11;	12+11;	8+12;	4 (no tentacles)			0.9
37	400	15	5	5+ 7	7+ 6;	8+ 7;	10.5+ 4.5;	2+ 1			—
38	405	—	—	8+ 7	4 (tentacles inverted);	6.5+ 4.5;	8+ 9;	8+ 7			0.5
39	422	18	5	10+ 7	14+ 6;	12+ 7;	17+ 7;	8+ 8			0.8
40	475	22	7	14+11	11+12;	16+17;	15+10;	15+16			—
41	530	21	5	16+11	16+16;	15+15;	16+12;	16+10			0.8
42	535	18	7	10+ 8	14+ 8;	12+ 5;	15+10;	15+ 9			0.9
43	570	17	2	12+ 9	12+ 9;	14+11;	12+10;	15+12			0.8
44	390	18	7	6+ 6	12+ 8;	9+11;	9+ 8;	10+ 9;	14+ 9		0.9
45	404	17	9	12+ 7	14+ 9;	14+11;	15+ 8;	13+13;	12+10		0.9
46	420	18	5	9+ 8	13+ 7;	11+ 8;	13+ 9;	13+ 8;	12+ 8		0.9
47	440	26	1	12+14	13+13;	17+18;	15+17;	13+20;	15+15		0.8
48	700	18	3	14+ 9	12+10;	15+10;	17+10;	16+ 9;	15+11		0.7
49	?	20	6	9+15	14+16;	14+19;	12+15;	12+16;	12+18;	15+15	0.8
50	?	40	17	18+20	25+19;	28+24;	28+25;	26+23;	30+24;	29+23	1.5
51	?	40	13	18+18	23+22;	25+23;	24+25;	24+19;	24+24;	24+25	1.5
52	?	45	18	21+16	27+22;	22+21;	24+18;	28+21;	28+25;	24+19	1.5
53	?	30	5	14+10	18+ 8;	20+ 9;	25+ 7;	26+18;	26+ 7;	28+14; 23+10	1.0

Text-fig. 2. *Umbellula güntheri*. Measurements in mm.

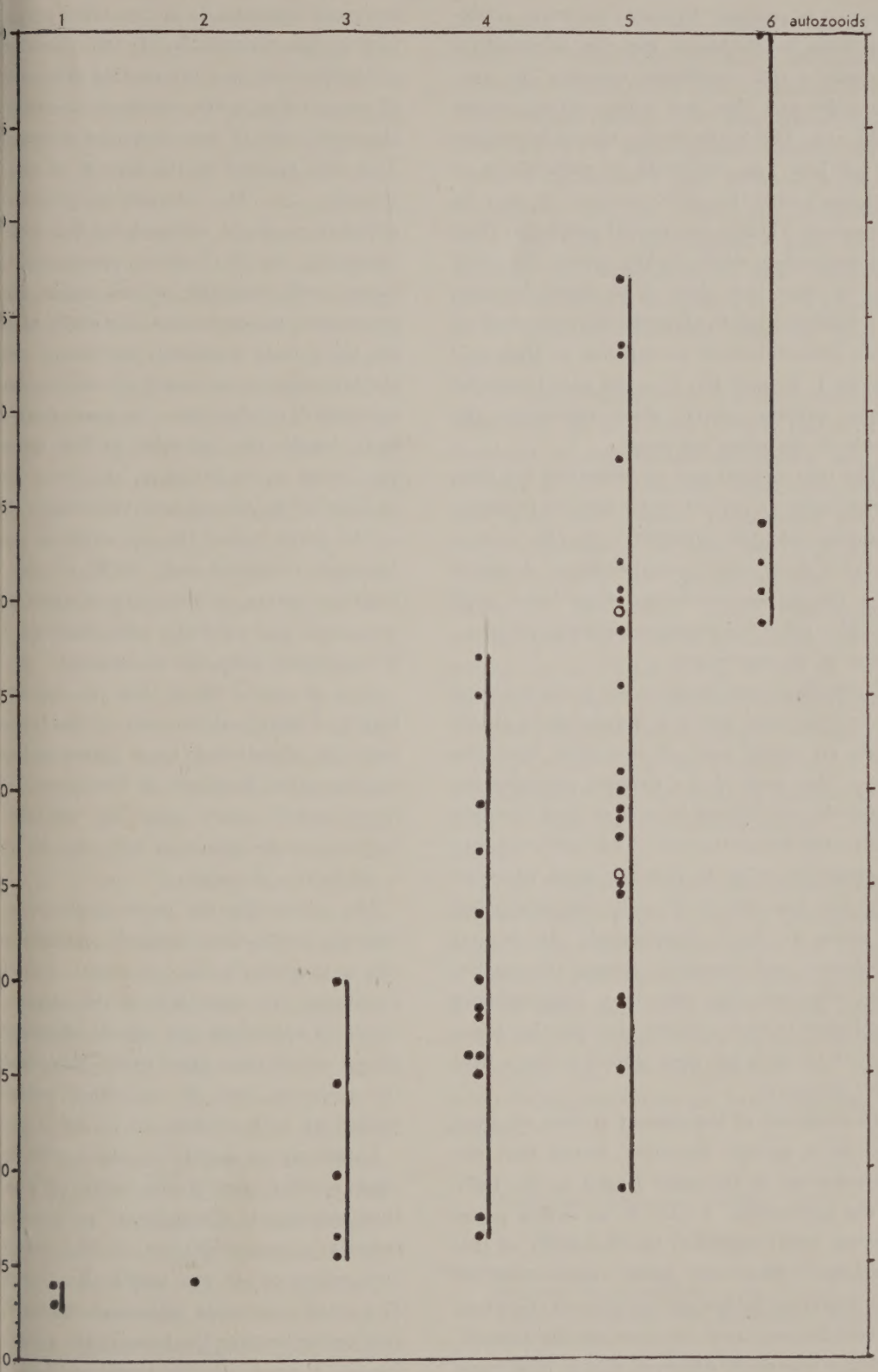


Fig. 3. *Umbellula güntheri*. Total lengths of specimens with 1 to 6 autozooids. The diagram illustrates the y varying size of specimens with equal numbers of autozooids. Each dot represents one specimen. Rings denote he primary polyp is missing, but that the cluster otherwise belongs to this group (comp. Text-fig. 1, VI c and d).

rounded in section. Upwards the stalk gradually loses its fleshiness and the coenenchym becomes a thin membrane covering the quadrangular and thin, but comparatively rather rigid, axis. It is in the present species impossible to tell how long the stalk or peduncle is as compared with the entire sea-pen. It may be a question whether one should not better drop the designation »stalk» in this genus. The bulb and the part just above it no doubt function as a holdfast; but in all probability the stalk of other pennatularians corresponds to Hickson's regions I, II, and III, i. e., the part below the upper swelling which alone represents the rachis of the other sea-pens.

The thin median part of *Umbellula* has been looked upon as part of rachis because it carries siphonozooids; this however, is also the case in stalks of some other pennatularians. A search after the siphonozooids and their lower limit should involve mikrotome sectioning and mutilation of the specimens.

In the larger specimens we can in the majority discern the bulb, but it is impossible to distinguish an upper part of the stalk from the lower, thin part of the »rachis», probably because the soft tissues have here been strongly contracted during the haul. This view evidently is strengthened by the frequent cases, when the bulb also has been so strongly contracted that it seems to have disappeared. In several specimens, and especially among the smaller ones, the bulb has also been longitudinally contracted to such a degree that the thin lower part of the axis has been curved in like a fish-hook within it.

In diagnoses of the present species we often find as a specific character stated that the tentacles are of the same length as the body in the autozooids. I have in an earlier paper (Broch 1913) suggested the invalidity of this character. The very great contractility of pennatularian polyps and colonies on the whole is well known from observations in aquaria, and it is here easily observed that in most cases body and tentacles do not contract prop ally in the autozooids. In the prese collection there is a remarkable differen of contraction in the specimens as wel the autozooids of one cluster in several This also appears in the figures of the (text-fig. 2). The autozooids present different stages of contraction, some o (especially in the largest specimens) rather well extended, others again st contracted; in some cases it is easily see the polyp body is strongly contracted, w the tentacles are extended or only mod contracted, or vice versa. In percentage body length the tentacles in the coll vary from 43 to 167, i. e., they may b as long or up to one and two thirds a as the polyp body. (In one extreme ca tentacles measured only 33 % of the length; however, as the polyp in questi very small and evidently not outgrown, been omitted from the discussion.)

It is at once evident that the compa length of body and tentacles of the auto must be abandoned as a principal s fundamentum divisionis in *Umbellula*. investigations must clear up whethe feature in some species or other can be u a secondary character.

The autozooids are generally more strongly contracted, curiously enough, ally comparatively less contracted in the specimens. In some few of the largest extended autozooids the spicula seeming placed a little more apart in the polyp wa the tentacles, but all the other polyp packed up with spicula.

Larger siphonozooids do not appear upper swollen part of the rachis till th three autozooids (the primary polyp an secondary autozooids) are all but out-p In a colony of 145 mm length (No. 7, te 2) a small number of siphonozooids wer just visible between the bases of the autoz but in a much greater specimen with

ids (No. 8) siphonozooids were not at all. In many small specimens with utozooids the siphonozooids may as yet cult to observe and in such cases may ly be found in small numbers between es of the autozooids and on the rachis ow them. Only in very few exceptional an siphonozooids be seen on the sides of shaft between the cluster and the »stalk». spicula are three-flanged, and although nges or ridges are little prominent and s almost only indicated, and in spite of ner rich equipment with small warts or they are easily distinguished from the ds of *Umbellula durissima* (see below, . 7). In the present material the spicula agree with the descriptions and figures n an earlier paper (BROCH 1913).

eems almost certain that *Umbellula* is synonymous with the species des- by KÖLLIKER in 1874 and therefore to be named *Umbellula thomsoni*. I owever, put a query to this synonym there are some discrepancies in the ions in his both first publications and nograph of the Challenger pennatula- In his first paper (1874 a) KÖLLIKER n translation) that »the 13 polyps are d in a way that they form outward ng oblique rows, so that to the right rs of three polyps each and to the left r of three and one of two polyps are to these are added one seemingly ter- ndividuum and one single to the right hind the latter.» His second and some- more extensive description (1874 b), r. indicates that the largest specimen 13 autozooids placed in one simple The length of this specimen was 895 d we get the impression that Kölliker ore him a very large specimen of the species and that its autozooids, accord- his last account, were seated as we have expected them after the devel- as illustrated by text-fig. 1. In 1880 KÖLLIKER again expresses himself more indistinctly, and in 1915 KÜKENTHAL in his diagnosis returning to KÖLLIKER's first publication writes »die Polypen stehen . . . in anscheinend schief nach a u s s e n aufsteigenden Reihen von je 2 oder 3 Individuen.» This, however, is clearly at variance with the present line of development, and I have therefore put a query to the synonym and maintained the name *Umbellula güntheri* given by KÖLLIKER in 1880 to a species which doubtless coincides with the present specimens.

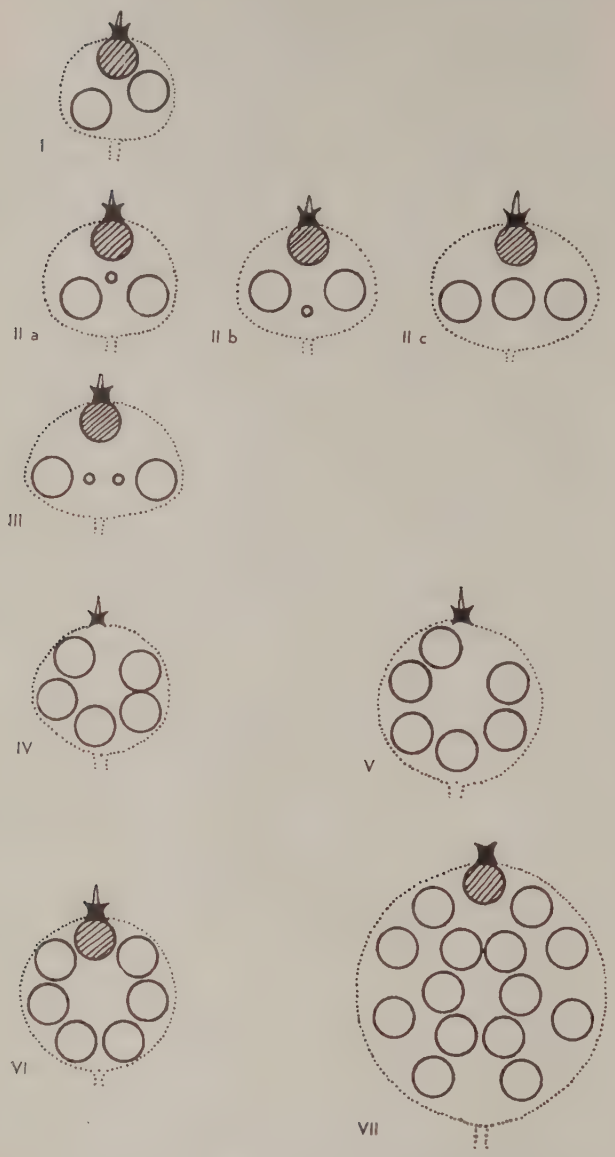
The smaller specimen of *Umbellula thomsonii* mentioned by KÖLLIKER (1874 a) had 5 fully developed autozooids and corresponds thus to text-fig. 1, VII. However, KÖLLIKER writes that there were 5 more, rudimentary polyps without tentacles at the basal side of the polyp cluster ventrally (in his nomenclature »dorsally») on the rachis. These rudimentary polyps cannot be traced in his excellent photographs (1974 b, Tafel I, Fig. 4 and 5). The photographs show the greatest conformity with the present species, but the alleged rudimentary 5 polyps make the identity uncertain. A reinvestigation of his specimens is necessary in order to settle the probable synonymy of our species.

In the Challenger report KÖLLIKER (1880) also described a couple of smaller development stages of the present species under the names of *Umbellula leptocaulis* and *Umbellula simplex*. Also THOMSON and HENDERSON (1906) instituted some new species based on stages in the development of *Umbellula güntheri;* but their rather deficient descriptions have hampered a revision.

Umbellula carpenteri Kölliker 1880.

(Plate I, Fig. 2—4, textfig. 4—6).

Umbellula carpenteri, Kölliker 1880, Report on the Pennatulidae. Challenger Zool., p. 23.
— *Köllikeri*, Kükenthal 1902, Zoologischer Anzeiger Bd. 25, p. 595.
— *carpenteri*, Hickson 1907, Ceolentera Alcyonaria, p. 12.



Text-fig. 4. *Umbellula carpenteri*. Diagrams of the autozooid clusters (a spine at the upper side of the axis section indicates that the terminal part of the rachis with the axis juts out above the basis of the primary polyp). I—III the 5 small specimens from haul No. 4 (comp. Text-fig. 5), IV and V two somewhat aberrant specimens from haul No. 4, VI the medium sized specimen and VII the two great specimens from haul No. 13 (comp. Text-fig. 6).

— *carpenteri*, Jungersen 1907, Pennatuliden, Belgica, p. 5.
— *carpenteri* + *U. Jordani* + *U. gilberti*, Nutting 1908, Descriptions of the Alcyonaria . . . . . Hawaiian Islands, p. 564, 565.
— *carpenteri* + *U. Köllikeri*, Kükenthal und Broch 1911, Pennatuliden, Valdivia, p. 284, 298.
— *carpenteri*, Nutting 1912, Descriptions of t cyonaria . . . . . Japanese waters, p. 43.
— *Carpenteri*, Kükenthal 1912, Die Alcyonar deutschen Südpolar-Expedition, p. 345.
— *carpenteri* + *U. köllikeri*, Kükenthal 1915, tularia, p. 285, 298.
— *jordani*, Hickson 1916, The Pennatulacea Siboga Expedition, p. 133.

Although the material of this spec scanty in comparison with that of *Uml günther*i, we also here can obtain some hi the development of the autozooid cluster fig. 4). The small specimens from haul (comp. text-fig. 5) markedly differ fro corresponding stages of *Umbellula gü* Their autozooids are placed somewhat apart and especially, there is a rather c cuous distance between the primary poly the secondary autozooids.

The smallest specimen of the collection I, fig. 2) already has two well develop condary autozooids (text-fig. 4, I) whic placed a little unsymmetrically belov primary polyp. The terminal part of the with the uppermost end of the axis i embedded in the wall of the primary poly juts out above it as a short, slender spi the diagrams, text-fig. 4, this is indicat the »spine» at the upper side of the axis se

In the next stage (II a and b) the secondary autozooid has appeared betwe two first ones; it may be seated a little (a) or below (b) the bases of them. In a specimen (II c) the third autozooid see have arisen all but simultaneously wit two lateral ones. — In the last of these specimens (Plate I, fig. 4, text-fig. 4, II autozooids have budded between the two first secondary autozooids, but th being slightly different they seem to arisen successively.

There is a gap between these small c and a couple of medium sized specimens moreover give the impression of being aberrant. In spite of the much greater the specimens their polyps are remarkabl

Total length of the specimen	Upper swollen part of rachis			Primary polyp: length of body + tentacles	Secondary autozooids: length of body + teatacles				Diameter of the axis	Length of the bulb of the stalk	Trawling Nr.
	Total length	naked part above the polyps	naked part below the polyps								
31	10	2	2.5	2+3.5	3.5+3.5;	3.5+3.5			0.4	4	4
36	6	1	1	2.3+2.8	3+3;	3+3;	2.5+2.5		0.4	2	4
39	8	2	1	1.8+2	3+3;	3+3;	2+2.5		0.4	0.3	4
31	6	1	1.5	1.5+?	3+3.5;	3+?;	1.5+?		0.4	2.5	4
43	9.5	1	3	2.5+3	4+4.5;	5+5;	1+?;	2+?	0.5	3.5	4

Text-fig. 5. *Umbellula carpenteri.* Measurements in mm of the 5 small specimens from haul No. 4.

) crowded that it is exceedingly difficult ıke out their arrangement. This is the difficult because each of the strongly ıcted polyps has curled and twisted and ervowen with the others. The extreme end of the rachis is very conspicuous and ɔut rather far above the polyp cluster. ɔf these specimens (text-fig. 4, IV) has utozooids in a circle, none of them, how- distinguishes itself as the primary polyp. in another colony from the same haul fig. 6, No. 8 and text-fig. 4, V) with six ɔoids it is impossible to point out the ry polyp with any certainty.

e primary polyp is on the other hand located in a more normal looking spec- from haul No. 13 (text-fig. 4, VI and ig. 6, No. 6); here seven autozooids are sitting in a simple wreath. — Two large specimens from the same haul possibly give us the definitive, normal arrangement of the polyps in outgrown specimens (text-fig. 4, VII). Here the primary polyp could at once be established although no »spine» is found at its dorsal side, the terminal part of the axis being now included in the body wall of the primary autozooid. In both specimens the comparatively large autozooids are placed in two wreaths. The outer circle consists of 9 autozooids (including the primary polyp), whereas the inner circle has only 6 autozooids.

Some few siphonozooids were observed in the smallest specimen already, although not between the autozooids but on the flattened sides of the thin part of the rachis below the cluster. The same was the case in No. 2 (text-fig. 5),

Total length of the specimen	Upper swollen part of rachis			Length of the autozooids, body + tentacles	Axis diameter		Length of the stalk	Length of the bulb	Trawling Nr.
	Total length	Naked part above the autozooids	Naked part below the autozooids		Just below the swollen upper part of rachis	At transition to the stalk			
180	10	1	2.5	strongly contracted: 7—10, tent. inverted	0.5	1.0	40	10	13
288	10	2.5	1	strongly contracted: 5, tent. inverted	0.5	1.0	40	?	4
302	11	2.5	3	strongly contracted: 5+?	0.8	1.0	38	?	4
1,050	35	0	10	20—27+10—15	1.5	2×3.5	180	20	13
1,190	40	0	10	25—32+20—22	1.5	2	?	20	13

g. 6. *Umbellula carpenteri.* Measurements in mm of the medium sized and large specimens from haul Nos. 4 and 13. (Nos. 7 and 8 coincide with Text-figs. 4, V and IV respectively.)

whereas siphonozooids could not be seen in the small specimens Nos. 3 and 4. In the 43 mm long specimen No. 5 on the other hand siphonozooids were found on the swollen part of the rachis in one single row round the basis of each autozooid, whereas no siphonozooid was visible on the thin part below the cluster.

In the medium sized specimens siphonozooids could not be seen, but in the two large specimens from haul No. 13 the siphonozooids were easily seen although evidently they were contracted; at all events the tentacles was withdrawn in all of them. Siphonozooids occur crowdedly on the swollen upper part of the rachis between the autozooids as well as below them, and regular rows of siphonozooids could be seen also along the flat sides of the slender stem.

The stalk as defined by KÜKENTHAL (1915) and HICKSON (1916) is generally more distinct in *Umbellula carpenteri* than in the preceeding species. In moderately contracted specimens the stalk has the repetitiously pictured shape somewhat recalling a very slender hourglass, and it is supported by a feebly thickened region of the axis which, however, again becomes very thin where it is included in the basal bulb. The tissues of the stalk, and especially those of the bulb are evidently in the *Umbellula* species (as also in the other pennatularians) capable of very great contractions and dilatations. The present specimens have of course been strongly irritated by the maltreatment in the gear which probably always causes contractions of varying intensities. This often results in disfigurements of the specimens. In several cases the bulb is not discernible. This was e. g., the case in the strongly contracted, medium-sized specimens from haul No. 4 (text-fig. 5, No. 7 and 8), and such contractions may also efface the upper limit of the peduncle even in large specimens like the largest specimen from haul No. 13 (text-fig. 6, No. 10).

The present species has doubtless been mentioned under different names in the ture since 1907. It is at present scarcely ible to trace the identity of several of because some descriptions are too curs even defective. JUNGERSEN (1907) g conscientious description of a series of mens from the antarctic expedition »Belgica». However, already the followin NUTTING (1908) after having identified *bellula carpenteri* in Hawaiian waters Pacific from the same domain describe »new species», *Umbellula jordani* and *Um gilberti* which certainly must be inclu *Umbellula carpenteri* in spite of which H (1916) from the Siboga expedition me specimens of the first of these two species the *Umbellula köllikeri* diagnosed by K THAL (1902) and described in detail by K THAL und BROCH (1911) from the G Valdivia-Expedition must be included synonym in *Umbellula carpenteri*.

Umbellula durissima Kölliker 188

(Plate I, Fig. 5, textfig. 7)

Umbellula durissima, Kölliker 1880, Report on th tulidae. Challenger Zool., p. 16.

— *durissima* + *U. dura*, Thomson and H 1906, An Account of the Alcyonarians. alcyonarians of the Deep Sea, p. 92, 93.

— *durissima*, Thomson and Ritchie 1906, cyonarians of the Scottish National Antar pedition, p. 859.

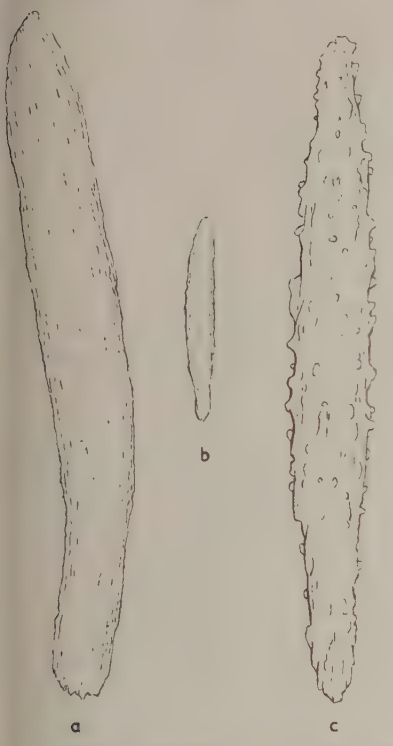
— *eloisa*, Nutting 1912, Description of the A . . . . . Japanese waters, p. 43.

— *durissima* + *U. dura* + *U. eloisa*, Kükent Pennatularia, p. 56.

— *durissima*, Hickson 1916, The Pennatulac Siboga Expedition, p. 126.

Only one specimen of this very teristic species was brought home Swedish Atlantic expedition, and the sp is defective, the lower part wanting with its single autozooid (Plate I, fig seems a little aberrant.

KÖLLIKER (1880) in his description *bellula durissima* remarks that the of the upper part of the stalk »have the three edges». THOMSON and HENDERSON



g. 7. *Umbellula durissima.* a A large spiculum
he tentacle stem, b small spiculum from the ten-
em and the body wall of the autozooid, and c a
piculum under higher magnification. (a and b
× 60, c × 180).

t mention these edges, but KÜKENTHAL in his diagnosis writes »Spicula kommen l vor. In den Polypen und Tentakeln s bis 3 mm. lange, dreiflügelige Nadeln, m Polypenkörper in 8 Bändern ange- t sind.» HICKSON (1916) on the other emphasizes that »The spicula appear to cular in section.» NUTTING (1912) gives graphs of the large spicula in *Umbellula* ; they show the terminal knob-like ngs which are rather characteristic of resent species, although they occur only ne 50 per cent of the great spicules. specimen from the Swedish expedition s that Hickson is right in his charac- tion of the spicula. Great or small they lways all but circular in section, and of them is threeflanged or three-ridged. great, single autozooid of the specimen is richly furnished with spicula of very characteristic shape and structure (text-fig. 7).

Large rods (text-fig. 7, a) form a narrow band along the aboral side of the pinnulae adjoining the stronger band of such spicula which stretches along the outer side of the tentacle stem; this band, however, disappears on the body wall shortly below the basis of the tentacle. These great rods which may attain a length of some 3 mm, are almost straight or a little bent and have blunt ends, in many cases a little swollen and knob-like.

Beside this obvious band of great spicules several smaller, fusiform spicula (text-fig. 7 b) are found in the tentacle stem, and together with yet smaller spicula of the same form and structure they are found crowded in the wall of the autozooid as well as in the tissues of the rachis. A somewhat greater enlargement of the spicula (text-fig. 7 c) reveals that they are furnished with small warts and granulations on the surface, but there are no hints at longitudinal ridges or flanges.

These features of the spicula, especially the aboral bands of the tentacles with their extraordinarily large spicula, together with the almost circular section of the axis make the identification of the present species rather easy.

The specimen at hand is only a fragment of the thin part of the rachis and the swollen upper end with its one single, great autozooid. There is no trace of any secondary autozooid in spite of the great size of the primary polyp (Plate I, fig. 5), and in spite of that the fragment according to its dimensions on the whole seems to have belonged to a large specimen. The great primary autozooid seems to sit on top of the rachis, the axis ending in the dorsal polyp wall. No distinct limit can be seen between rachis and polyp wall, but the tissues have been very strongly contracted and the upper end of the axis therefore is curved in to the ventral side so that it has taken the shape of a fish-hook. The resistance

of the axis is evidently the reason why the swollen part of the rachis is laterally strongly compressed.

The specimen gives us an interesting glimpse as to the value of a couple of features which have hitherto been used as specific characteristics. First a dorsal or lateral flattening of the polypiferous part of rachis. This, of course, is in most cases mainly due to contractions and must therefore be looked upon with suspicion and great caution. Such contractions will in species with strictly bilaterally built polyp-clusters doubtless also give rise to a varying breadth of the naked dorsal field as observed in the preceding species. A second character is the incurvation and spiral twisting resp. of the upper part of the thin rachis with its axis. Hickson (1916) based his *Umbellula weberi* mainly on the spiral twisting of the upper part of its axis below the polyp cluster. His drawing of the species shows the siphonozooids on the swollen upper part of the rachis (»region II») as short streaks parallel with the axis. This coincides with their appearance in the present specimen of *Umbellula durissima* below the basis of the single autozooid and must in some way or other be correlated with the contraction, and neither this nor the incurvation of the upper part of the axis can be used as specific criteria.

Some zoogeographic remarks

The three *Umbellula* species brought home by the Swedish Deep-Sea Expedition have a very extensive habitat in the deep-sea of the oceans. A review of the earlier known localities is needed in connection with the synonymy given above.

Umbellula güntheri:

Atlantic Ocean

(?) N 35° 20′, W 13° 04′, 3,768 m (*thomsonii*).
N 01° 47′, W 26° 46′, 3,380 m.
Off Morocco, 2,000 and 2,125 m.
Guadeloupe (»Blake» St. 162), 1,336 m.
N 29° 08′, W 22° 53′, 5,160 m.
N 28° 54′, W 26° 46′, ?

Indian Ocean

N 11° 58′, E 88° 52′, 3,190 m (*rosea*).
N 12° 20′, E 85° 08′, 3,290 m (*henderson*

Pacific Ocean

S 13° 50′, E 151° 49′, 4,460 m (*leptocaul*
N 36° 10′, E 178° 00′, 3,750 m (*simplex*).
N 04° 56′, E 80° 52′ 30″, 3,240 m.

The species evidently has its home i deep-sea, and it seems to prefer depths g than 3,000 m, but it may exceptionally h with in much lesser depths as evinced b finds near Morocco in 2,000 m and at deloupe even in 1,336 m depth. Nevert *Umbellula güntheri* avoids the cold ant water as far as we know today and has events not hitherto been found in ant subantarctic territories, although it has found in several localities both in the At Indian, and Pacific Oceans. The speci also not been met with in the more no parts of the Atlantic and Pacific Oceans, an influence of water from the Arctic may possibly be the cause.

Umbellula carpenteri:

Antarctic seas

S 53° 55′, E 108° 55′, 5,310 m.
S 62° 20′, E 95° 44′, 3,560 m.
S 70° 40′, W 102° 15′, 2,800 m.
S 78° , E 174° , 540 m.
Near Gauss-Berg, 2,450 and 2,725 m.

Indian Ocean

S 01° 47′ 08″, E 41° 58′ 08″, 1,670 m (*köl*
S 05° 40′, E 120° 45′, 1,158 m (*jordani*).

Pacific Ocean

Near Hawaii, 930—2,050 m.
Off Kaui, Hawaii, 680—2,400 m (*jorda*
Off Kaui, Hawaii, 400—1,950 m (*gilbert*

mar Saki Light, Japan, 919 m.
44′, E 144° 02′, 928 m.

bellula carpenteri is remarkably eurybath,
ibitat according to the present data
g from 400 m and downwards to 5,310
l although most southern specimens have
taken below some 2,000 m, we cannot
certainty point out which parts of the
n of the deep-sea the species prefers.
remarkable that the finds in Antarctic
s as well as in the Atlantic have been
at greater depths than those in Indo-
c waters, where the species seemingly
s depths lesser than 2,000 m and has
met with also as shallow as about 400 m.
mbellula carpenteri is a southern species
evidently rather common in the Antarctic
sea. On the other hand, it penetrates far
wards in the Atlantic Ocean (at all
s to some 40° N), and it is also not
n in Pacific waters in any case as far
as Japan and Hawaii. Nevertheless the
s has not been stated as found in the
ern parts either of the Pacific or of the
tic Ocean.

llula durissima:

arctic seas
06′, E 10° 05′, 3,185 m.

Indian Ocean

Off the Laccadives, 2,070 m.
N 10° 06′, E 92° 29′, 1,300 m (*dura*).
S 03° 27′, E 131° 00′, 1,012 m.

Pacific Ocean

N 34° 07′, E 138° 00′, 1,030 m.
Off Shio Misaki Light, Japan, 1,092 m (*eloisa*).

This species evidently has its home from 1,000 m and downwards, and the greatest depth stated up till now is from the Swedish expedition where the single specimen was caught between 4,430 and 4,474 m depth. It is on the whole difficult to say where the central habitat of the species is. Only single individuals have been found in few and very scattered localities. The depths of the earlier finds vary from 1,012 to 3,185 m; one single locality in the Antarctic Ocean with its 3,185 m has up till now held the depth record, all other finding places being from 1,000 to 2,000 m deep. — *Umbellula durissima* had previously only been reported from the Antarctic, Indian, and Pacific Oceans, and it was surprising now to find it, so to say, in the centre of the Atlantic Ocean also. The reason why the species is so seldom caught by the common bottom gears, must probably be sought in its comparatively thin and remarkably flexible stem.

References

z, A., Three cruises of the U. S. Coast and Geodetic Survey Steamer »Blake». *Bull. Mus. Comp. Zoöl.* 1888, *14—15*, p. XXII, 314, 320.

, Hj., Pennatulacea. *Rep. Sci. Res. »Michael Sars» North Atlant. Exp. 1910*, 1913, *3*, p. 1—9.

LSSEN, D. C., and KOREN, J., Pennatulida. *Norw. North-Atlant. Exp. 1876—1878*, 1884, Zool. *4*.

MANN, E., The Alcyonaria of the western part of the Atlantic Ocean. *Mem. Mus. Comp. Zoöl.*, 1936, *53*, p. 1—317.

ON, S. J., Coelentera Alcyonaria. *Nat. Antarct. Exp., Nat. Hist.* 1907, *3*, p. 1—15.

The Pennatulacea of the Siboga Expedition. *Siboga-Exp.*, 1916, *14*, p. I—X, 1—265.

RSEN, H. F. E., Pennatulida. *Dan. Ingolf-Exp.* 1904, *5*, p. 1—91.

— — Pennatuliden. *Rés. Voy. Belgica 1897—98—99, Rapp. Sci., Zool.*, 1907, p. 1—22.

KÖLLIKER, A., Ueber den Bau und die systematische Stellung der Gattung Umbellularia. Eine vorläufige Mittheilung. *Verh. Phys.-Med. Ges. Würzburg*, 1874 a, *8*, p. 13—18.

— — Die Pennatulide Umbellula und zwei neue Typen der Alcynarien. *Festschr. Phys.-Med. Ges. Würzburg*, 1874 b, p. 1—24.

— — Report on the Pennatulida. *Rep. Sci. Res. Challenger, Zool.*, 1880, *1*, 1—41.

KÜKENTHAL, W., Diagnosen neuer Umbelluliden. *Zool. Anz.* 1902, *25*, p. 595.

— — Die Alcyonaria der deutschen Südpolar-Expedition. *Deutsche Südpolar-Exp.*, 1912, *13* (*Zool. 5*), p. 287—349.

KÜKENTHAL, W., Pennatularia. *Das Tierreich*, 1915, *43*, p. I—XV, 1—182.

KÜKENTHAL, W., und BROCH, HJ., Pennatulacea. *Wiss. Ergebn. deutsch. Tiefsee-Exp.*, 1911, *13*, p. I—VI, 113—576.

NUTTING, C. C., Descriptions of the Alcyonaria collected by the U. S. Bureau of Fisheries Steamer »Albatross» in the vicinity of the Hawaiian Islands in 1902. *Proc. U. S. Nat. Mus.*, 1908, *34*, p. 543—601.

— — Descriptions of the Alcyonaria collected by the U. S. Fisheries Steamer »Albatross», mainly in Japanese waters, during 1906. *Proc. U. S. Nat. Mus.*, 1912, *43*, p. 1—104.

ROULE, L., Notice préliminaire sur les Pennatu ceuillis par le »Travailleur» et »Talisma l'Ocean Atlantique. *Bull. Mus. Hist. nat* 1905, *11*.

STUDER, TH., Note préliminaires. *Bull. Mus. Zoöl.* 1894, *25*.

THOMSON, J. A., and HENDERSON, W. D., *An A the Alcyonarians collected by the R. I. M vestigator in the Indian Ocean. I. The Alcy of the Deep Sea.* Calcutta, 1906.

THOMSON, J. A., and RITCHIE, J., The Alcyona the Scottish National Antarctic Expedition *Roy. Soc. Edinburgh*, 1906, *41*.

Explanation of plate 1.

Fig. 1. *Umbellula güntheri*. Specimen from haul No. 10 with only one autozooid (the primary polyp). × 2.

Fig. 2. *Umbellula carpenteri*. Specimen No. 1 (Text-fig. 5) with two secondary autozooids. a dorsal, b ventral view. × 2.

Fig. 3. *Umbellula carpenteri*. Specimen No. 4 (Text-fig. 5) with three secondary autozooids (Diagram Text-fig. 4, II c). a dorsal, b ventral view. × 2.

Fig. 4. *Umbellula carpenteri*. Specimen No. 5 (Text-fig. 5) with two large and two small secondary autozooids. a dorsal, b ventral view. × 2.

Fig. 5. *Umbellula durissima*. Primary polyp in side view, also showing the strong incurvation of the upper part of the axis. Nat. size.

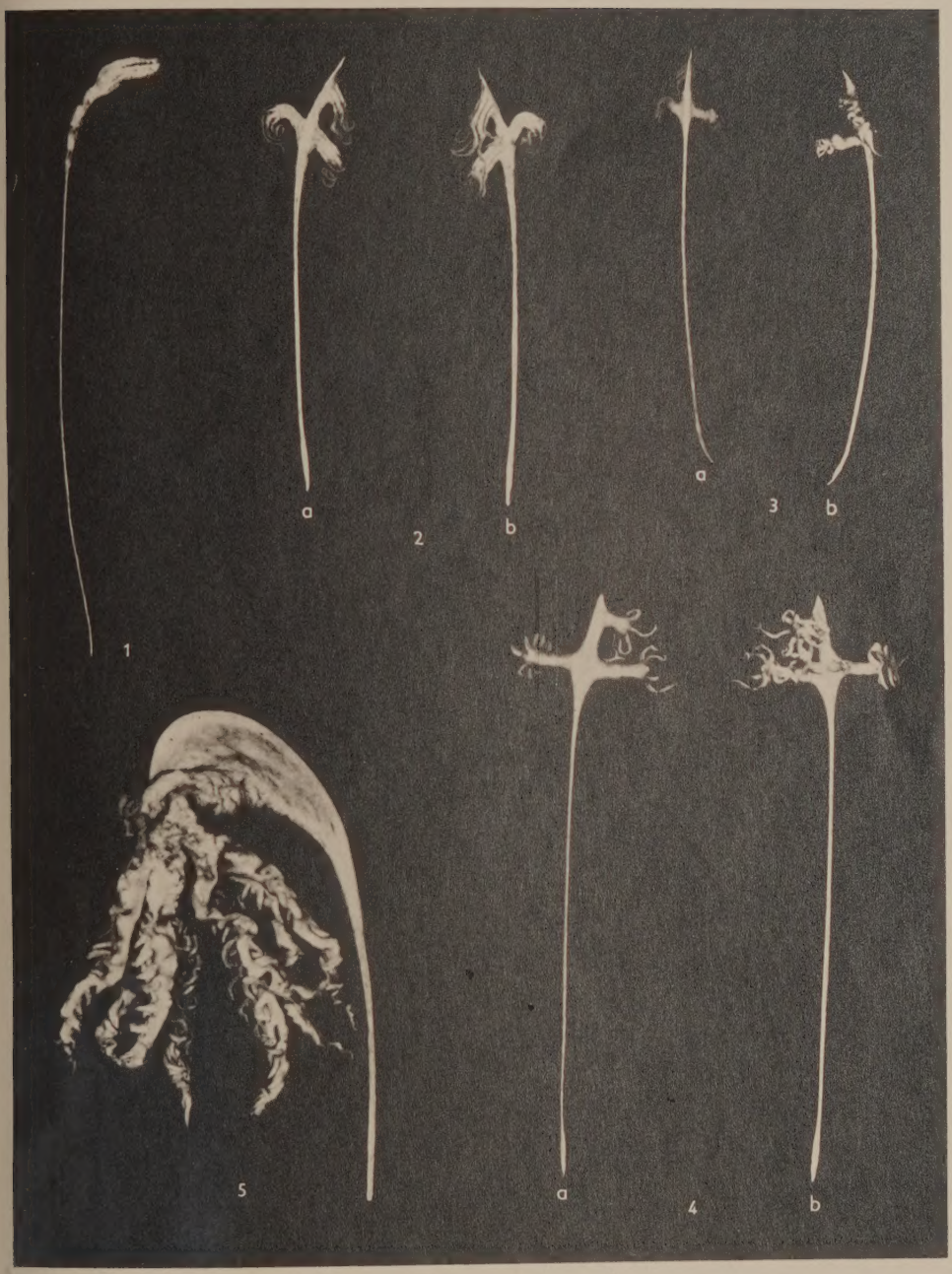


Photo: O. Bakke.

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